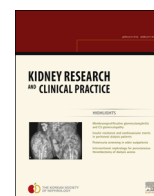




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Original Article

Clinical outcome of percutaneous thrombectomy of dialysis access thrombosis by an interventional nephrologist



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Background: Traditionally, the treatment of a thrombosed dialysis access in hemodialysis patients in Korea has been primarily performed by vascular surgeons and interventional radiologists. The objective of this study was to evaluate the outcome of percutaneous thrombectomy procedures performed by an interventional nephrologist.

Methods: From October 2010 to May 2014, 75 consecutive percutaneous thrombectomies were performed on 42 patients treated with maintenance hemodialysis. All percutaneous thrombectomy procedures were performed by an interventional nephrologist in a single hospital in Jeju, Korea. The thrombosed arteriovenous graft and arteriovenous fistula were declotted by thromboaspiration mechanical thrombectomy or pharmacomechanical thrombolysis. Kaplan–Meier survival analysis was performed to analyze the primary and secondary patency after the initial successful thrombectomy. Success and complication rates were identified and compared with the recommendations of the Kidney Disease Dialysis Outcomes Quality Initiative (KDOQI) guideline.

Results: The overall clinical success rate was 89.3% (67/75). In the successful cases, the postintervention primary (unassisted) patency rates at 30 days, 90 days, and 180 days were 79.9%, 56.6%, and 25.6%, respectively. The secondary patency rates at 30 days, 90 days, and 180 days were 92.2%, 85.7%, and 83.7%, respectively. There were no major complications, and all complications were treated successfully during the procedure.

Conclusion: The clinical success rate and primary patency rate at 3 months exceeded the recommendations of the KDOQI guideline, and were comparable to that of other reports. Percutaneous thrombectomy by an interventional nephrologist was safe and effective.

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Introduction

In Korea, > 52,000 patients currently undergo maintenance hemodialysis as a renal replacement therapy, and the proportion

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of elderly and diabetic patients is growing rapidly [1]. Along with the rapid increase of the hemodialysis population and the hemodialysis life expectancy, the incidence of vascular access complications has also grown at an exponential rate. As such, maintaining a durable dialysis access has become even more challenging. Above all, dialysis access thrombosis remains a nightmare to hemodialysis patients and the dialysis staff. The necessity for a temporary hemodialysis catheter owing to an occluded vascular access can cause much apprehension, pain,

and deterioration in the quality of life in a hemodialysis patient. As such, thrombosis of arteriovenous fistula (AVF) and arteriovenous graft (AVG) should be treated as soon as possible without unnecessary delay and within 48 hours, prior to the next dialysis session. Early declotting allows for immediate use of the access without the need for a central venous catheter [2]. At the same time, the current Kidney Disease Dialysis Outcomes Quality Initiative (KDOQI) clinical practice guidelines emphasize that each institution should monitor the outcome of the treatment on the basis of graft patency following percutaneous thrombectomy [3].

Traditionally, the treatment of thrombosed dialysis access in hemodialysis patients in Korea has been performed by vascular surgeons and interventional radiologists. However, interventional nephrologists are quickly developing into specialists that actively perform dialysis access interventional procedures, and percutaneous thrombectomy by interventional nephrologists has become popular worldwide in recent years.

In the current study, we retrospectively reviewed percutaneous thrombectomy by an interventional nephrologist in a single hospital and report the outcome according to the criteria from the Society of Interventional Radiology (SIR) [4] and the recommended criteria in the KDOQI guidelines.

Methods

Patient population

Seventy-five percutaneous thrombectomy procedures were performed by an interventional nephrologist in a single hospital in Jeju, Korea. All referred patients from other dialysis centers were sent back to the referring doctors after successful treatment, and successful hemodialysis was confirmed by telephone survey to both the patients and dialysis centers.

In this study, access thrombosis was defined as a clinical status that meets all of the following criteria: a totally occluded access without thrill and bruit as seen by physical examination; with thrombus, as confirmed by ultrasonographic examination; and an accesses inability to be used for hemodialysis treatment. Patients were excluded from percutaneous thrombectomy if they had an infected vascular access or severe contrast allergies. There were three cases excluded owing to infected access during this study.

We retrospectively reviewed an existing database from our angiographic unit of consecutive percutaneous thrombectomy procedures for thrombosed arteriovenous fistulas and grafts. This single-center retrospective study was approved by the Korea National Institute for Bioethics Policy (IRB number, P01-201408-RS-01-00), and informed consent was obtained prior to the thrombectomy procedures.

Procedure technique

Devices

In all cases, we performed duplex Doppler ultrasound examinations with LOGIQ P5 (GE Healthcare, Salt Lake City, UT, USA) prior to the declotting procedures. All percutaneous thrombectomy procedures were performed in an angiography suite equipped with an INNOVA 3100 Angiographic Imaging System (GE Healthcare). We used devices, such as a noncompliant balloon catheter (Cook, Bloomington, IN, USA) for thrombus maceration and angioplasty, a 5F Fogarty thrombectomy

balloon catheter (Edwards Lifesciences, Irvine, CA, USA) for arterial plug removal, and a Desilets–Hoffman sheath (Cook) for thrombus aspiration.

Declotting procedures

Declotting procedures for AVG thrombosis were performed using either a crossed-catheter technique [5] or an apex puncture technique [6].

In the loop arteriovenous graft, the apex puncture technique was performed for thromboaspiration using a 7F Desilets–Hoffman sheath. The apex of the loop graft was punctured with a 21G micropuncture needle set (Cook), and a 7F Desilets–Hoffman sheath was inserted toward the venous limb. If a central vein stenosis was present, percutaneous transluminal balloon angioplasty (PTA) was performed prior to declotting. A thromboaspiration mechanical thrombectomy, using a Desilets–Hoffman sheath, was performed to remove the clot from the venous limb of the graft. Any significant (> 50%) stenoses in the outflow vein and venous anastomosis were treated by using an over-the-wire noncompliant balloon catheter (Cook) or a high-pressure balloon catheter (Conquest Balloon; Bard, Inc., Covington, GA, USA). After declotting of the venous limb, the sheath was redirected into the arterial limb for thromboaspiration and PTA. If an arterial plug was found, a 5F non-over-the-wire Fogarty thrombectomy balloon catheter was used to dislodge the clot into the arterial limb. After the restoration of a thrill in the access, a diagnostic fistulogram was obtained via digital subtraction analysis to inspect any residual stenotic lesions and complications. If residual thrombus was detected beneath the sheath, the Fogarty balloon catheter was used to dislodge the thrombus and re-establish the flow [7]. In the straight-configuration AVG, a crossed-catheter technique with dual access was applied and the declotting process was performed in the same manner as explained for the loop AVG thrombectomy. After sheath removal, hemostasis was achieved with a modified purse-string suture technique [8]. After a successful thrombectomy, the dialysis access was immediately used for hemodialysis treatment.

The declotting procedures for AVF thrombosis were performed essentially the same way as those in AVG thrombectomies. There was, however, a difference in the sheath approach between the AVG and AVF thrombectomy procedures. The approach for the AVG thrombectomy could be made by using a relatively standard pattern, but the approach for the AVF thrombectomy had to be individually applied according to the characteristics of each AVF and the various causes of thrombosis [9].

Hybrid technique

In particular cases, such as those with large volumes of hard clots within a huge aneurysm, we also performed a hybrid technique (surgical thrombectomy in combination with endovascular angioplasty) [10]. A 2–3 cm transverse skin incision was made over the dialysis access, followed by its dissection from the surrounding tissue. After the vascular clamps were located proximally and distally, a transverse venotomy was made. Then the thrombus was removed with a 5F Fogarty balloon catheter. The remaining thrombus was removed by manual squeezing. A balloon angioplasty was performed for the stenotic lesions using a noncompliant balloon catheter, and a fistulogram with digital subtraction analysis was

obtained. If the stenotic lesions were successfully treated by the balloon angioplasty, the venotomy was closed by a micro-surgical technique using 6–0 polypropylene sutures. All hybrid technique procedures were successfully performed in the angiography unit by an interventional nephrologist without complications.

Definitions of outcome

According to the reporting standards from the SIR [4], technical success was defined as the restoration of flow combined with a residual stenosis of less than 30%, as based on a good thrill. Clinical success was considered to have been achieved when it functioned normally for at least one subsequent hemodialysis session, in addition to the technical success of the declotting procedure. The postinterventional primary patency was defined as the interval after the percutaneous thrombectomy until the next access thrombosis or any subsequent access intervention. The postinterventional secondary patency was defined as the interval after the percutaneous thrombectomy until the access was surgically declotted, revised, or abandoned. Complications were classified as either minor or major in accordance with the reporting standards of the SIR [4].

Statistical analysis

The data are presented as mean \pm standard deviation or the percentage. Kaplan–Meier survival analysis was performed to analyze the primary and secondary patency rates after the initial successful thrombectomy. For data analysis and presentation, the R project, version 3.1.0 (The R Foundation for Statistical Computing, Vienna, Austria), was used. For the analysis of patency, the datasets were censored in the cases of patient death, transplantation, and loss of follow-up.

Results

Baseline characteristics

From October 2010 to May 2014, 75 consecutive thrombectomy procedures were performed on 42 patients (27 men and 15 women) with a mean age of 64.5 ± 11.0 years. Among the 42 patients, 34 were diagnosed with AVG and 8 with AVF thrombosis. The mean age of the dialysis access at the time of thrombectomy was 39.5 ± 41.9 months (range, 3–223 months; median, 30 months). The percutaneous thrombectomy cases in AVG and AVF were 67 (89.3%) and eight (10.7%), respectively. In the configuration of AVG, the loop type accounted for 61.2% (41/67) and the straight type accounted for 38.8% (26/67). The baseline characteristics of percutaneous thrombectomies are presented in Table 1.

Access survival rate

The clinical success rates of AVG and AVF thrombectomy were 89.5% (60/67) and 87.5% (7/8), respectively. Among the loop AVG thrombectomies, 53.7% (22/41) of the declotting procedures were performed through the apex puncture technique, which was 90.9% (20/22) successful. In three cases, mechanical thromboaspiration thrombectomy was performed

Table 1. Baseline characteristics

Characteristic	Value
Number of patients	42
Number of percutaneous thrombectomies	75
Male/female	27:15 (64.3:35.7)
Patient age (y \pm SD)	64.5 \pm 11.0
Dialysis access age (mo \pm SD)	39.5 \pm 41.9
Number of procedures in diabetic patients	39 (52)
Location of dialysis access	
Forearm	26 (34.7)
Upper arm	49 (65.3)
Type of AV fistula	
Radiocephalic	5 (62.5)
Brachiocephalic	3 (37.5)
Configuration of AV graft	
Loop	41 (61.2)
Straight	26 (38.8)
Location of AVG stenosis*	
Arterial anastomosis	8 (11.9)
Venous anastomosis	49 (73.1)
Outflow vein	15 (22.4)
Central vein	9 (13.4)
Number of stenoses in a thrombosis case†	
0‡	4
1	45
2	24
3	2

* A thrombosed AV graft often had multiple stenoses at the same time.

† Overall, 94.7% of thrombosed access had significant stenosis.

‡ In four cases of AVG thrombosis, significant stenosis was not found. AV, arteriovenous; AVG, arteriovenous graft; SD, standard deviation.

Table 2. Features of percutaneous thrombectomy

Method	Success rate (%)
Crossed-catheter technique	39/45 (86.6)
Apex puncture technique in loop AVG*	20/22 (90.9)
Hybrid technique†	5/5 (100)
Modified pharmacomechanical technique	3/3 (100)
Overall success rate	67/75 (89.3)

* Two cases of failure in apex puncture technique were attributable to central vein occlusion and intervention withdrawn for surgical revision of venous anastomotic stenosis, respectively.

† Hybrid technique was performed in three cases in AVF thrombosis and two cases in AVG thrombosis.

AVF, arteriovenous fistula; AVG, arteriovenous graft.

with a combination of a modified pharmacomechanical thrombolysis technique [11].

There were seven technical failures during AVG thrombectomy, which were followed by surgical thrombectomy.

Table 2 summarizes the features of the percutaneous thrombectomy procedures in this study.

For all successful thrombectomy cases, the postintervention primary (unassisted) patency rates at 30 days, 90 days, and 180 days were 79.9% [95% confidence interval (CI), 70.7–90.3%], 56.6% (95% CI, 45.4–70.5%), and 25.6% (95% CI, 16.0–41.0%), respectively; the secondary patency rates at 30 days, 90 days, and 180 days were 92.2% (95% CI, 85.8–99.0%), 85.7% (95% CI, 77.5–94.8%), and 83.7% (95% CI, 74.8–93.5%), respectively. For the successful cases of AVG thrombectomy, the postintervention primary (unassisted) patency rates at 30 days, 90 days, and 180 days were 79.3% (95% CI, 69.5–90.4%), 58.8% (95% CI, 47.2–73.4%), and 28.8% (95% CI, 18.2–45.5%), respectively; the secondary patency rates at 30 days, 90 days, and 180 days were 93.0% (95% CI, 86.7–99.9%), 87.7% (95% CI, 79.5–96.7%),

and 85.4% (95% CI, 76.5–95.4%), respectively. The Kaplan–Meier survival curve of the postintervention primary and secondary patency of the AVG thrombectomy is shown in Fig. 1.

Discussion

The KDOQI Vascular Access Guidelines emphasize that each institution should monitor the outcome of treatment on the basis of graft patency after percutaneous thrombectomy [3], and recommend a clinical success rate of > 85%. In this study, our overall clinical success rate was 89.3% (67/75), whereas the clinical success rate of AVG thrombectomies was 89.5% (60/67).

There were seven technical failures during AVG thrombectomy; the causes were as follows: failure to pass the guidewire through a totally occluded central vein (2 cases); an incomplete removal of hard, adhesive clots within the large pseudoaneurysm (2 cases); > 30% residual stenosis owing to a diffuse, thickened neointimal hyperplasia in the graft lumen (1 case); and an intervention withdrawn by the operator's choice (2 cases). In the two withdrawn cases, a surgical

thrombectomy with revision was performed subsequently. In the failed case of AVF thrombectomy, a technical success was achieved, but the function of the AVF was inadequate for subsequent hemodialysis treatment.

According to the KDOQI guidelines, the majority of reported 3-month primary (unassisted) patency rates range from 30% to 40% after percutaneous thrombectomy [12–16]. The Work Group of KDOQI emphasized that percutaneous thrombectomy should achieve a 3-month primary patency rate of > 40%. In this study, the 90-day primary patency rates of the total cases and of the AVG cases were 56.6% and 58.8%, respectively. These outcomes exceed the recommended criteria of 40%, and are comparable to the results of previously reported studies [17–23] (Table 3).

There were no major complications that required hospitalization with surgical or medical treatment, and all of the complications were treated successfully during the procedures. There were two cases of minor vein dissection during AVF thrombectomy and three cases of distal arterial embolization during AVG thrombectomy. Distal arterial emboli were percutaneously retrieved successfully during the procedure in two cases, and observed in one other case, which had no symptoms. Several months later, we performed a follow-up, which showed normal arteriogram without emboli. Two cases of minor vein dissection were also successfully treated by prolonged intraluminal balloon inflation during the procedure. Overall, the complication rate was 6.6% (5/75), and no cases of procedure-related death were noted.

Although there are a variety of techniques that have been introduced for mechanical thrombectomy, no clear advantage of one technique over another has ever been documented [9]. In this study, most of the thromboses were treated by a thromboaspiration mechanical thrombectomy using a Desilets–Hoffman sheath. For the declotting procedures of loop AVGs, we preferentially performed an apex puncture technique, which may overcome several of the disadvantages that result from the dual-access, crossed-catheter approach for loop AVG [6]. The Fogarty balloon application technique [7] was useful for compressing or displacing any sheath entry point residual thrombus that did not wash away spontaneously by arterial blood flow. When a residual thrombus was still present despite the use of a Fogarty balloon, it required an additional sheath insertion to remove the sheath entry point thrombus; we defined these steps as dual access, cross-catheter techniques and were hence excluded from the category of the apex puncture technique. In cases of a straight-configuration AVG, the crossed-catheter technique was routinely performed because the direction change of a single sheath was not favorable.

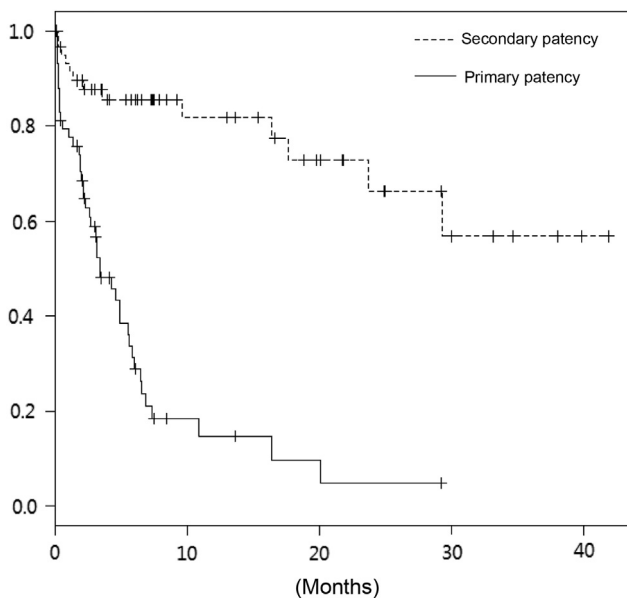


Figure 1. Kaplan–Meier survival curve for primary and secondary patency of arteriovenous graft (AVG) thrombectomy.

Table 3. Comparison of the outcomes in arteriovenous graft thrombectomy

Authors	Procedure number	Device	Technical success (%)	Complications (%)	Primary patency rate (%)	
					30 d	90 d
Sofocleous et al [18]	57	Amplatz	93	16	65	50
Trerotola et al [16]	64	Arrow-Trerotola	95	11	39	20
Lazzaro et al [19]	50	Arrow-Trerotola	100	14	42	
Barth et al [20]	62	Oasis	95	11	69	40
Trerotola et al [16]	58	PSPMT	95	22	40	25
Little et al [21]	20	Angiojet	95	12	80	57
Yang et al [22]	32	DHS	75	12.5	81	
Goo et al [23]	225	DHS	88.9	17.8		63.1
Goo et al [17]	2,531	DHS	96	12	76	62
Present study	67	DHS	89.5	6.6	79.3	58.8

DHS, Desilets–Hoffman sheath; PSPMT, Pulse-spray pharmacomechanical thrombolysis.

Two self-expanding nitinol stents were deployed across the venous anastomosis in the lesion refractory to PTA, and stents were used in 2.56% of the percutaneous thrombectomy procedures in this study. Stents are used sparingly in our center for cases of PTA-induced venous rupture or elastic recoil of stenosis with no surgical option, in accordance with KDOQI Vascular Access Guidelines [3].

All patients with dialysis access thrombosis that visited our center were imaged with Doppler ultrasonography prior to the declotting procedure, thus allowing for the selection of the more favorable method (percutaneous thrombectomy or surgical thrombectomy). During the preprocedural ultrasonographic examinations of AVF thrombosis, a large majority exhibited distinct causative lesions that tended to require surgical modifications in addition to the thrombectomy, and many cases of AVF thrombosis were treated via surgical thrombectomy by a vascular surgeon. It was common that an AVF thrombosis due to a juxta-anastomotic stenosis with calcified plaques was treated by proximal reanastomosis with surgical thrombectomy. This tendency of AVF thrombosis explains why cases of percutaneous thrombectomy in AVF thrombosis are relatively fewer than those of AVG thrombectomy in this study.

Here, we have focused on thrombectomies, not on entire endovascular procedures. The patency of a dialysis access after mechanical thrombectomy depends on the result of treatment for underlying stenoses [24,25], and clot removal is only a part of the procedure. An underlying stenosis is frequently (> 85%) the cause of AVG thrombosis [15,16], so a high success rate and longer patency include a successful angioplasty during the thrombectomy procedure. In addition, thrombectomy procedures are not elective but urgent. Most thrombosis episodes are found on the day of the hemodialysis treatment, especially for AVG. Therefore, emergency percutaneous thrombectomy is frequently required to have the hemodialysis treatment as scheduled. According to the European Best Practice Guidelines on Vascular Access, dialysis access thrombosis should be treated without unnecessary delay and within 48 hours, prior to the next dialysis session [2], and KDOQI guidelines recommend that thrombectomy procedures be performed as soon as possible to avoid the need for a central venous catheter [3]. Therefore, an evaluation of the outcomes of percutaneous thrombectomy procedures represents how well qualified the center is in performing emergency thrombectomies. In this study, all percutaneous thrombectomies were performed within 24 hours of diagnosis. There were no cases where hemodialysis treatment were not undertaken as scheduled, nor were central venous dialysis catheters needed, except in the cases of clinically failed percutaneous thrombectomy followed by a subsequent surgical thrombectomy.

This result indicates that if the nephrologists were actively involved in performing immediate diagnostic and therapeutic interventions, unnecessary delays in declotting procedures could be avoided by reducing the waiting time caused by referring patients between multiple departments.

Because nephrologists are typically the first doctor to notice a thrombosis event and the closest physician who can monitor vascular access for extended periods in the hemodialysis center, it would be ideal for the patients for the nephrologist to perform the salvage procedures for a clotted dialysis access. Owing to their unique perspectives on the hemodialysis treatment and hemodynamics of vascular access, these specialists are ideally suited to perform this activity. Indeed,

recent data have emphasized that nephrologists can safely and successfully perform these procedures with excellent results [9]. Likewise, the outcome of this study satisfied the recommendations of the KDOQI guidelines, and was comparable to other reports. Percutaneous thrombectomy performed by an interventional nephrologist was safe and effective, and this result was in accordance with current trends indicating that endovascular treatment by interventional nephrologists has become more popular worldwide.

Conflict of interest

None.

References

- [1] Current Renal Replacement Therapy in Korea, 2013. Available at: <http://www.ksn.or.kr/journal/2014/index.html> [Date accessed: 28 July 2014]
- [2] Tordoir J, Canaud B, Haage P, Konner K, Basci A, Fouque D, Kooman J, Martin-Malo A, Pedrini L, Pizzarelli F, Tattersall J, Vennegoor M, Wanner C, ter Wee P, Vanholder R: EBPG on vascular access. *Nephrol Dial Transplant* 22:ii88–ii117, 2007
- [3] National Kidney Foundation: K/DOQI clinical practice guidelines for vascular access. *Am J Kidney Dis* 48:S176–S276, 2006
- [4] Gray RJ, Sacks D, Martin LG, Trerotola SO: Reporting standards for percutaneous interventions in dialysis access. *J Vasc Interv Radiol* 14:S433–S442, 2003
- [5] Trerotola SO, Lund GB, Scheel Jr PJ, Savader SJ, Venbrux AC, Osterman Jr FA: Thrombosed dialysis access grafts: percutaneous mechanical declotting without urokinase. *Radiology* 191:721–726, 1994
- [6] Hathaway PB, Vesely TM: The apex-puncture technique for mechanical thrombolysis of loop hemodialysis grafts. *J Vasc Interv Radiol* 10:775–779, 1999
- [7] Goo DE, Yang SB, Kim YJ, Moon C, Song D, Yoon SC, Lee WH: Fogarty balloon application technique in dislodging residual thrombus on the single sheath entry point at the apex of thrombosed loop grafts. *Diagn Interv Radiol* 19:150–153, 2013
- [8] Simons ME, Clark TWI, Rajan DK: The woggle technique: a new method of suture closure of hemodialysis arteriovenous grafts and fistulas after percutaneous interventions. *J Vasc Interv Radiol* 12:S30, 2001. ([Abstract])
- [9] Beathard GA, Litchfield T, Physician Operators Forum of RMS Lifeline, Inc. Effectiveness and safety of dialysis vascular access procedures performed by interventional nephrologists. *Kidney Int* 66:1622–1632, 2004
- [10] Hyun JH, Lee JH, Park SI: Hybrid surgery versus percutaneous mechanical thrombectomy for the thrombosed hemodialysis autogenous arteriovenous fistulas. *J Korean Surg Soc* 81:43–49, 2011
- [11] Choi SY, Choi BG, Han KH, Chun HJ: Efficacy of a modified pharmacomechanical thrombolysis technique for endovascular treatment of thrombosed prosthetic arteriovenous grafts. *Korean J Radiol* 13:300–306, 2012
- [12] Falk A, Guller J, Nowakowski FS, Mitty H, Teodorescu V, Uribarri J, Vassalotti J: Reteplase in the treatment of thrombosed hemodialysis grafts. *J Vasc Interv Radiol* 12:1257–1262, 2001
- [13] Sofocleous CT, Hinrichs CR, Weiss SH, Contractor D, Barone A, Bahramipour P, Brountzos E, Kelekis D: Alteplase for hemodialysis access graft thrombolysis. *J Vasc Interv Radiol* 13:775–784, 2002
- [14] Vogel PM, Bansal V, Marshall MW: Thrombosed hemodialysis grafts: lyse and wait with tissue plasminogen activator or urokinase compared to mechanical thrombolysis with the Arrow-Trerotola percutaneous thrombolytic device. *J Vasc Interv Radiol* 12:1157–1165, 2001

- [15] Cohen MA, Kumpe DA, Durham JD, Zwerdlinger SC: Improved treatment of thrombosed hemodialysis access sites with thrombolysis and angioplasty. *Kidney Int* 46:1375–1380, 1994
- [16] Trerotola SO, Vesely TM, Lund GB, Soulen MC, Ehrman KO, Cardella JF: Treatment of thrombosed hemodialysis access grafts: Arrow-Trerotola percutaneous thrombolytic device versus pulse-spray thrombolysis. Arrow-Trerotola Percutaneous Thrombolytic Device Clinical Trial. *Radiology* 206:403–414, 1998
- [17] Goo DE, Kim YJ, Park ST, Yang SB, Yoon SC, Song D: Thromboaspiration of arteriovenous hemodialysis graft thrombosis using Desilets-Hoffman sheath: single-center experience. *J Vasc Access* 2014. Available at: <http://www.vascular-access.info/article/thromboaspiration-of-arteriovenous-hemodialysis-graft-thrombosis-using-desilets-hoffman-sheath-single-center-experience> [Date accessed: 28 July 2014]
- [18] Sofocleous CT, Cooper SG, Schur I, Patel RI, Iqbal A, Walker S: Retrospective comparison of the Amplatz thrombectomy device with modified pulse-spray pharmacomechanical thrombolysis in the treatment of thrombosed hemodialysis access grafts. *Radiology* 213:561–567, 1999
- [19] Lazzaro CR, Trerotola SO, Shah H, Namyslowski J, Moresco K, Patel N: Modified use of the arrow-trerotola percutaneous thrombolytic device for the treatment of thrombosed hemodialysis access grafts. *J Vasc Interv Radiol* 10:1025–1031, 1999
- [20] Barth KH, Gosnell MR, Palestrant AM, Martin LG, Siegel JB, Matalon TA, Goodwin SC, Neese PA, Swan TL, Uflacker R: Hydrodynamic thrombectomy system versus pulse-spray thrombolysis for thrombosed hemodialysis grafts: a multicenter prospective randomized comparison. *Radiology* 217:678–684, 2000
- [21] Littler P, Cullen N, Gould D, Bakran A, Powell S: AngioJet thrombectomy for occluded dialysis fistulae: outcome data. *Cardiovasc Intervent Radiol* 32:265–270, 2009
- [22] Yang SB, Goo DE, Kim DH, Lee HK, Choi DL, Kwon KH, Hong HS, Moon C: Percutaneous mechanical declotting of thrombosed dialysis graft. *J Korean Radiol Soc* 43:411–416, 2000
- [23] Goo DE, Kim JH, Park ST, Chang YW, Hwang JH, Kwon KH, Choi DL, Mun C: Usefulness of thromboaspiration with Desilets-Hoffman sheath in thrombosed hemodialysis access graft. *J Korean Radiol Soc* 51:45–53, 2004
- [24] Beathard GA: Percutaneous transvenous angioplasty in the treatment of vascular access stenosis. *Kidney Int* 42:1390–1397, 1992
- [25] Kanterman RY, Vesely TM, Pilgram TK, Guy BW, Windus DW, Picus D: Dialysis access grafts: anatomic location of venous stenosis and results of angioplasty. *Radiology* 195:135–139, 1995